# DER Interconnection Requirements

## *Need for Harmonization*

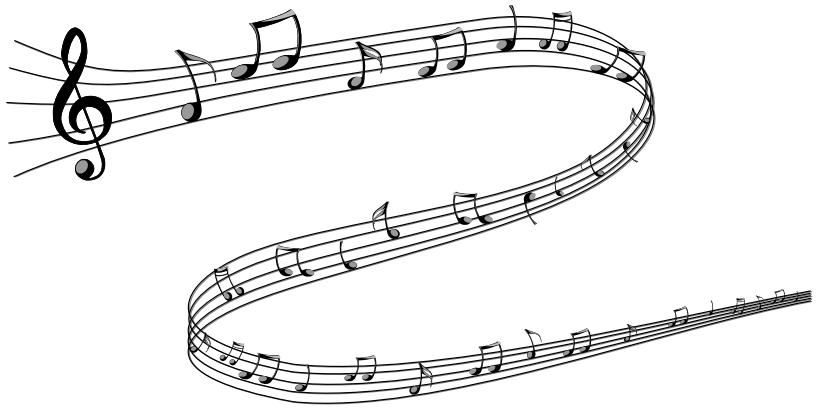
**Aminul Huque, PhD**
Technical Leader, Integration of DER, Electric Power Research Institute

**Integrating PV in Distribution Grids: Solutions and Technologies Workshop**
**Energy Systems Integration, NREL**

Golden, CO; October 23, 2015

# Presentation Outline

- IEEE 1547a-2014
  - Opportunities & flexibilities
- IEEE 1547-201X: Full Revision
  - Approach
  - Can it bring the harmony back



# Major Changes in IEEE 1547a-2014 Amendment

| IEEE 1547 – 2003/2008 | IEEE 1547a - 2014 |
| --- | --- |
| ▪ DR shall not actively regulate the voltage at the PCC | ▪ DR may actively participate to regulate the voltage by changes of real and reactive power |
| ▪ DR shall cease to energize if frequency >60.5Hz | ▪ DR shall be permitted to provide modulated power output as a function of frequency |
| ▪ Tighter abnormal V/F trip limits and clearance times | ▪ Much wider optional V & F trip limits and clearance times<br>▪ Under mutual agreement between the EPS and DR operators, other static or dynamic frequency and clearing time trip settings shall be permitted. |

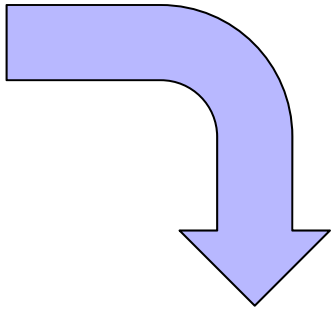
# Changes in "*Response to Abnormal Voltages*"

Table 1—Interconnection system response to abnormal voltages

| Voltage range (% of base voltage[a]) | Clearing time(s)[b] |
|---|---|
| V< 50 | 0.16 |
| 50 ≤ V< 88 | 2.00 |
| 110 < V < 120 | 1.00 |
| V ≥ 120 | 0.16 |

[a]Base voltages are the nominal system voltages stated in ANSI C84.1-1995, Table 1.
[b]DR ≤ 30 kW, maximum clearing times; DR > 30kW, default clearing times.

***IEEE 1547-2003/2008***



***IEEE 1547a - 2014***

**Table 1 ~~Default~~ Interconnection system default response to abnormal voltages**

| Default settings[a] | | |
|---|---|---|
| Voltage range (% of base voltage[b]) | Clearing time (s) | Clearing time: adjustable up to and including (s) |
| V < 45 | 0.16 | 0.16 |
| 45 < V < 60 | 1 | 11 |
| 60 < V < 88 | 2 | 21 |
| 110 < V < 120 | 1 | 13 |
| V > 120 | 0.16 | 0.16 |

[a] Under mutual agreement between the EPS and DR operators, other static or dynamic voltage and clearing time trip settings shall be permitted
[b] Base voltages are the nominal system voltages stated in ANSI C84.1-20~~06~~11, Table 1.

# Changes in "*Response to Abnormal Frequency*"

**Table 2—Interconnection system response to abnormal frequencies**

| DR size | Frequency range (Hz) | Clearing time(s)[a] |
|---|---|---|
| ≤ 30 kW | > 60.5 | 0.16 |
| | < 59.3 | 0.16 |
| > 30 kW | > 60.5 | 0.16 |
| | < {59.8 – 57.0} (adjustable set point) | Adjustable 0.16 to 300 |
| | < 57.0 | 0.16 |

[a]DR ≤ 30 kW, maximum clearing times; DR > 30 kW, default clearing times.

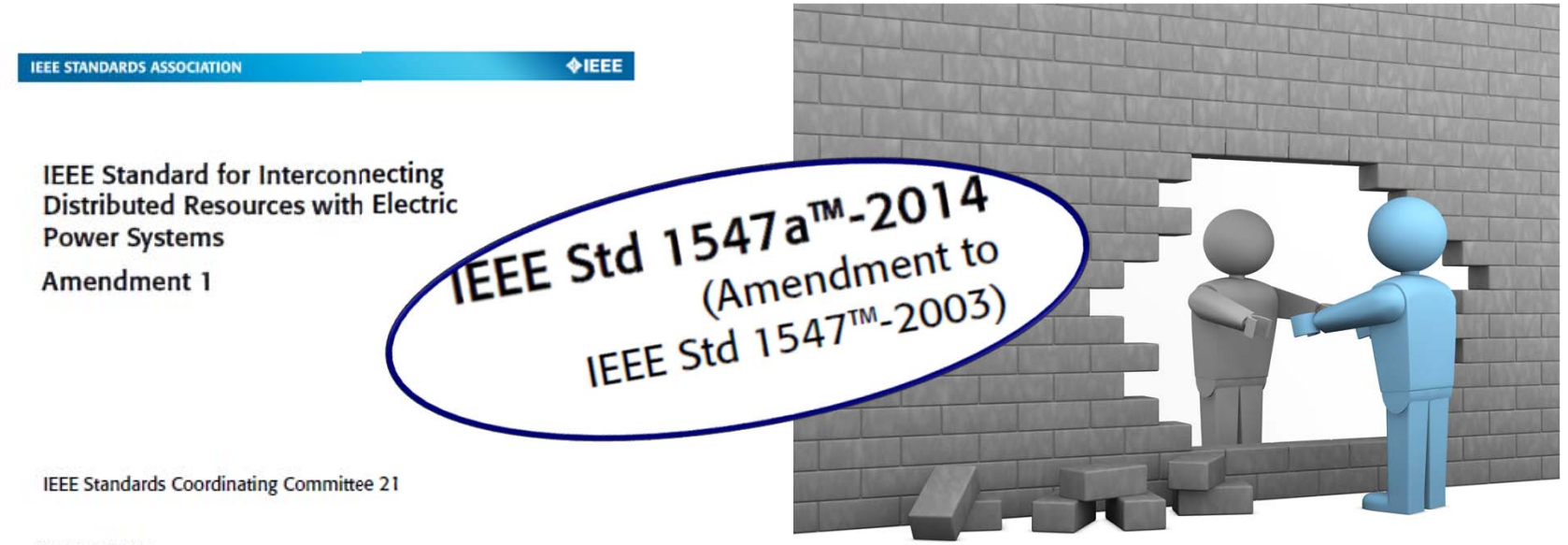
***IEEE 1547-2003/2008***

***IEEE 1547a-2014***

**Table 2—Interconnection system default response to abnormal frequencies**

| | Default settings | | Ranges of adjustability | |
|---|---|---|---|---|
| Function | Frequency (Hz) | Clearing time (s) | Frequency (Hz) | Clearing time (s) adjustable up to and including |
| UF1 | 57 | 0.16 | 56 – 60 | 10 |
| UF2 | 59.5 | 2 | 56 – 60 | 300 |
| OF1 | 60.5 | 2 | 60 – 64 | 300 |
| OF2 | 62 | 0.16 | 60 – 64 | 10 |

# IEEE 1547a™-2014

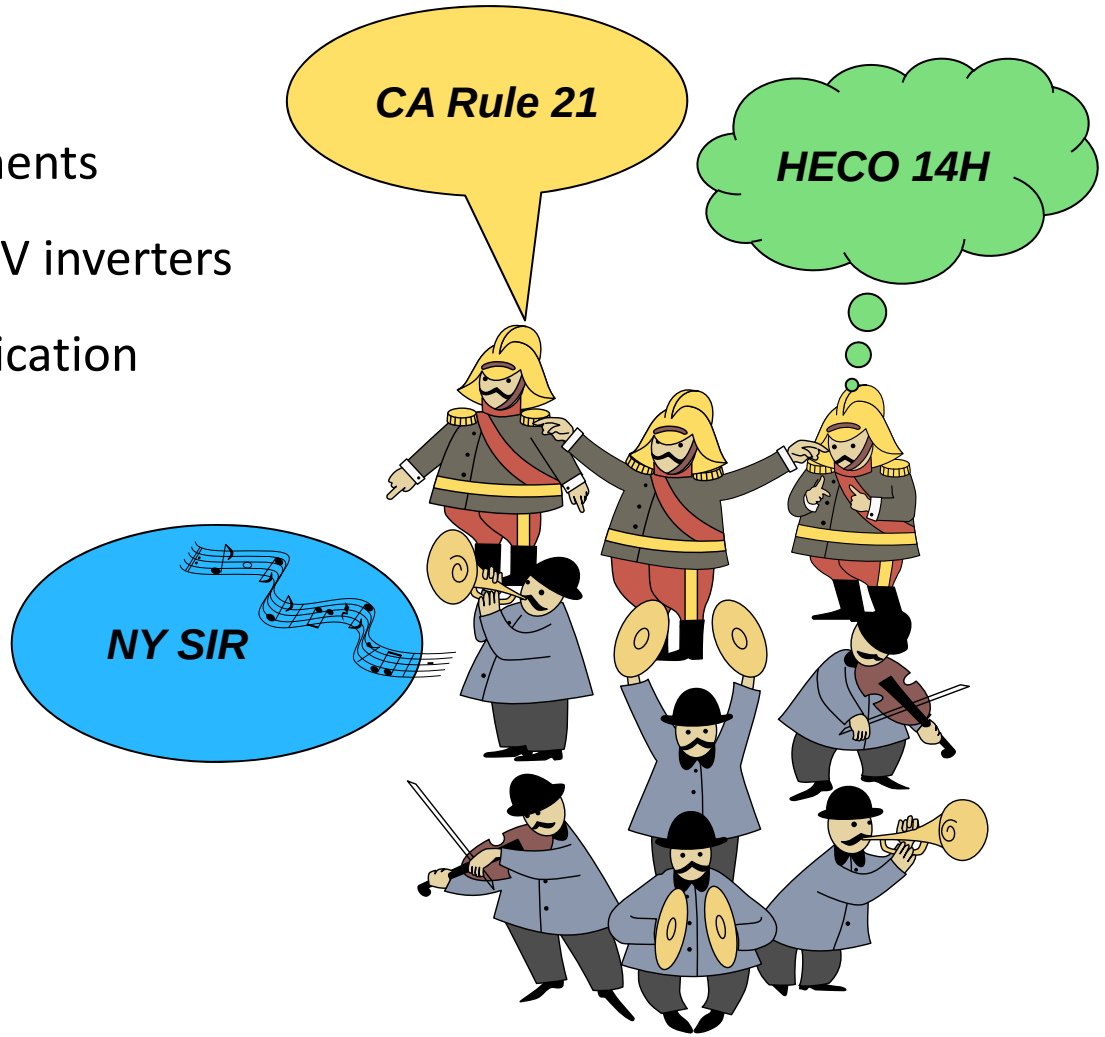



Opened the door for jurisdictions to create different interconnection requirements

But did not provide any direction

# The Reaction: Many Complicated Answers

- Technology-specific requirements
  - Heavily focused on solar PV inverters
- Creating challenges for certification



# NY State Standardized Interconnection Requirements (SIR)

## Under Consideration !

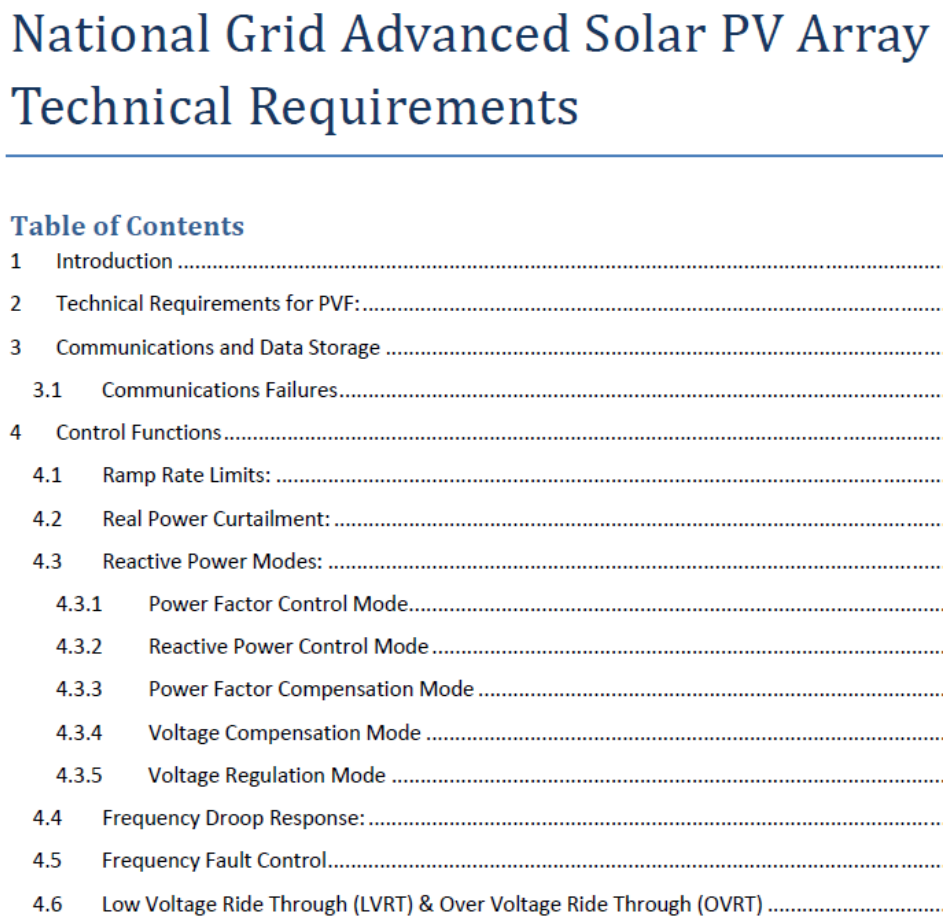
- For inverters rated at 250 kW and above shall be equipped with **static VAR control** *(need harmonization in function names)* as standard functionality. Settings shall be reviewed and approved by the utility during the application process and shall not be adjusted by the generator-owner after system installation and verification testing.
- All inverters shall include **frequency and ride through** functionalities as documented in IEEE 1547a*…(the 1547a allow, but doesn't define ride-thru)*
- Inverters shall be upgradeable with firmware for **dynamic power factor** control *(need harmonization in function names)*
- If deemed necessary due to abnormal system conditions the utility may request that the generator operate at **frequency ranges below 59.3 Hz** in coordination with the load shedding schemes of the utility system
- The utility reserves the right to reject system designs where **multiple inverters** with different manufacturers are used, where the conflicts between various anti-islanding algorithms is of concern

# Other Smart Inverter Initiatives

- National Grid's "Solar Phase II Initiative"

**Pilot smart inverter projects launched by:**

- Arizona Public Service (APS) company
- Salt River Project (SRP)

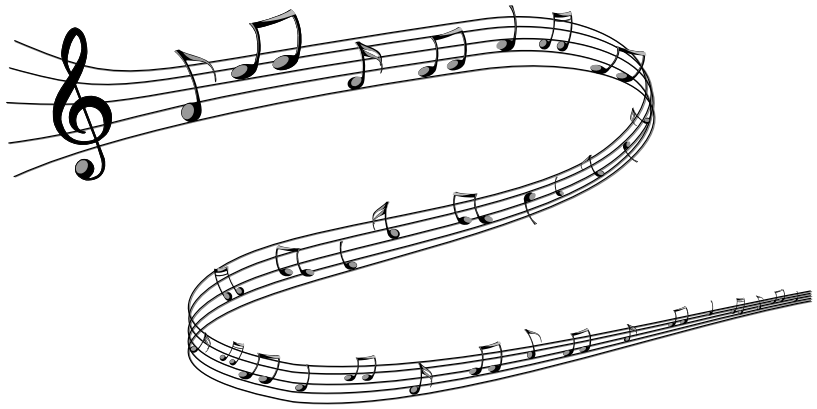


National Grid Advanced Solar PV Array Technical Requirements

Table of Contents

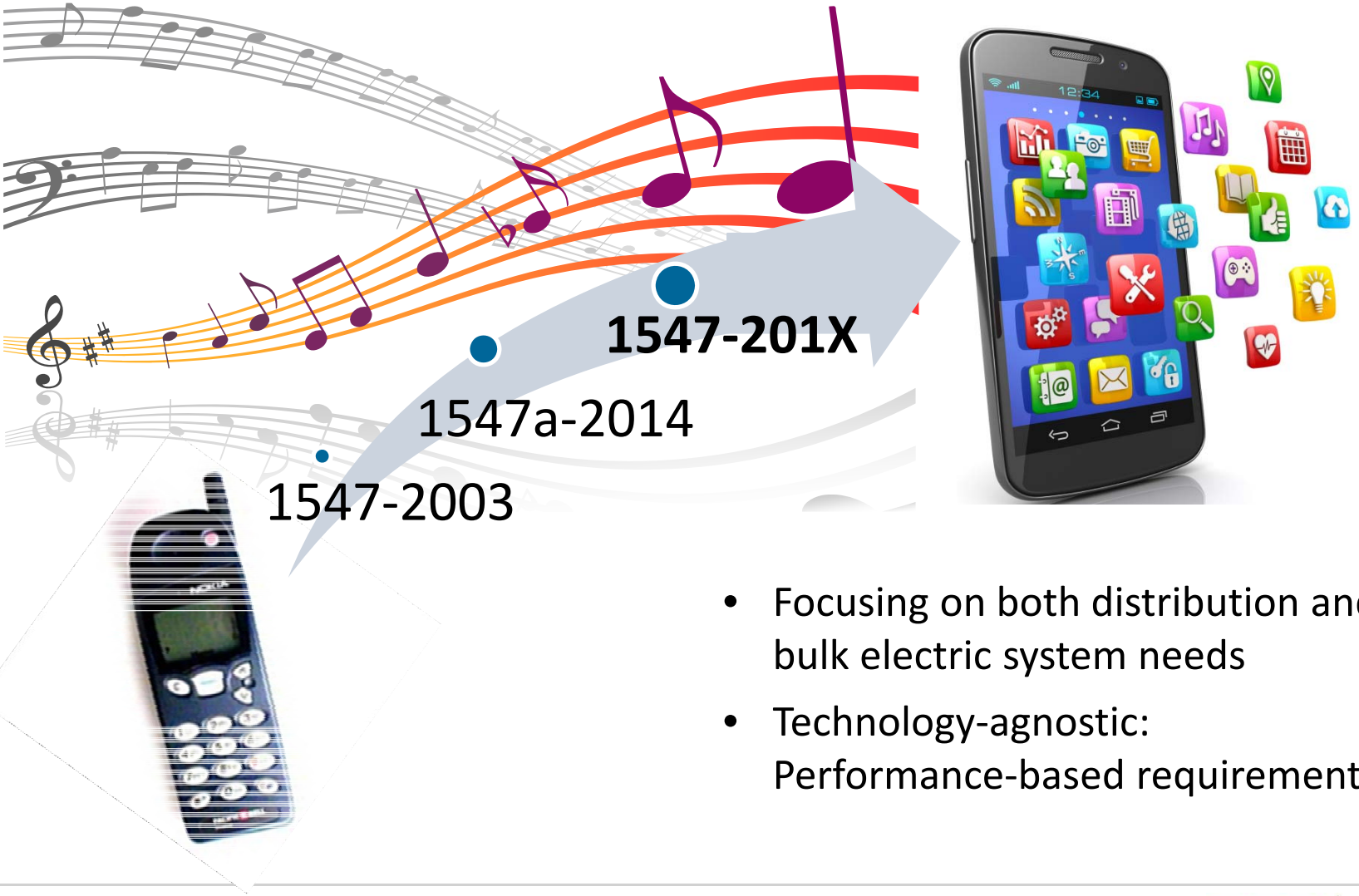
# Presentation Outline

- IEEE 1547a-2014
  - Opportunities & flexibilities
- **IEEE 1547-201X: Full Revision**
  - Approach
  - Can it bring the harmony back



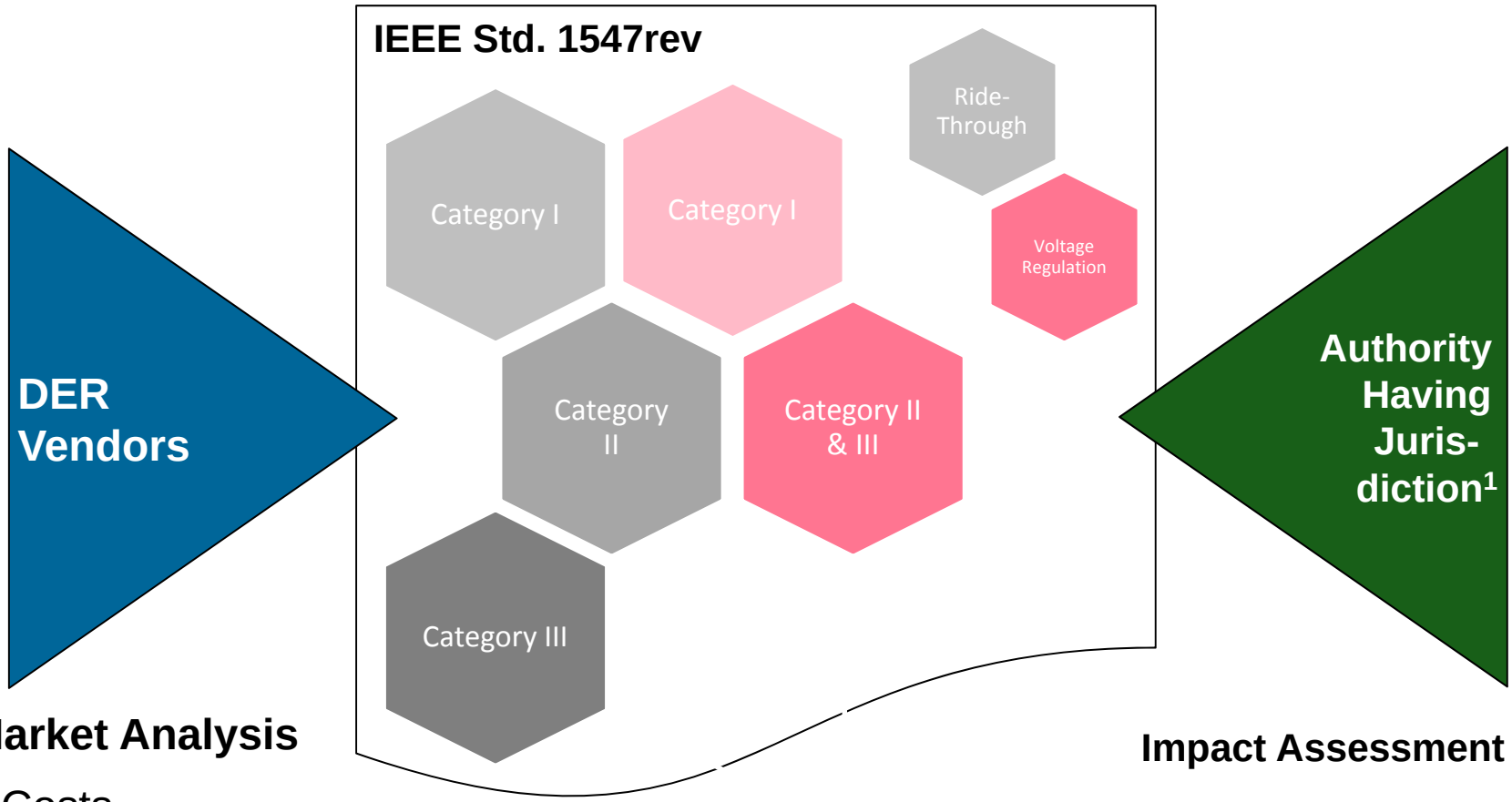
# IEEE P1547 – Full Revision

## Can it bring the harmony back?




- Focusing on both distribution and bulk electric system needs
- Technology-agnostic: Performance-based requirements

# IEEE P1547: Performance-Based Approach




**Market Analysis**

- Costs
- Market segment
- Etc.

**Impact Assessment**

- Type & capacity of DER
- DER penetration projection
- Type of grid configuration

1 State Regulator, Area EPS or bulk system operator, etc.

# General Requirement 1: Voltage Regulation Approach

*(Work-in-Progress)*

**4.1 General requirements**

**4.1.1 Reactive Power Capability of the DER**

**4.1.2 Voltage and Reactive Power Control**

- 4.1.2.1 Power Factor Mode
- 4.1.2.2 Voltage – Reactive Power (Volt-var) Mode
- 4.1.2.3 Active Power – Reactive (Watt-var) Mode
- 4.1.2.4 Reactive Power Mode

**4.1.3 Voltage and Active Power Control**

- 4.1.3.1 Voltage – Real Power (Volt-Watt) Mode


Other reactive and real power control modes and implementations ➔ shall be permitted under mutual agreement between the EPS and DER operators.

# 4.1.1 Reactive Power Capability of the DER

*(Work-in-Progress)*

The DER shall be capable of injecting reactive power to the Area EPS (over-excited) and absorbing reactive power from the Area EPS (under-excited) equal to the minimum reactive power (kVar) corresponding to the value given in Table TBD at all active power output equal to 20% to 100% of nameplate active power rating (kW).

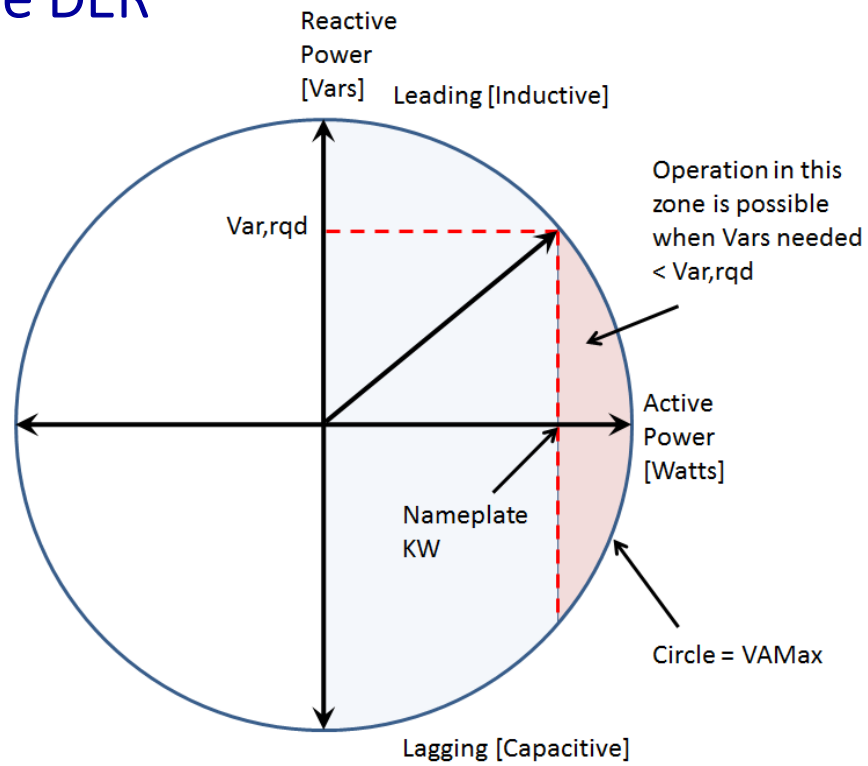


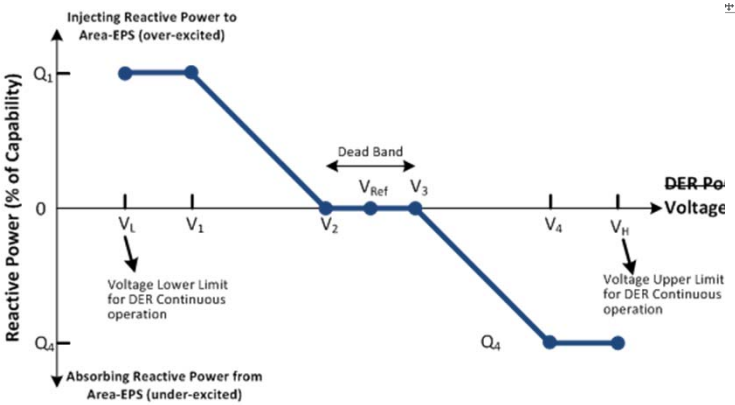

**Table TBD – Minimum Reactive Power Injection and Absorption Capability**

| Category | Injection Capability as % of Nameplate Apparent Power (kVA ) Rating | Absorption Capability as % of Nameplate Apparent Power (kVA ) Rating |
|---|---|---|
| I (at DER rated voltage) | 44<br>Full load PF=0.9 | 25<br>Full load PF=0.97 |
| II, III (at ANSI range A) | 44<br>Full load PF=0.9 | 44<br>Full load PF=0.9 |

# 4.1.2.2 Voltage – Reactive Power (Volt-var) Mode

*(Work-in-Progress)*

- When in this mode, the DER shall actively control its reactive power output as a function of voltage measured at any one location between the Electrical Connection Point (ECP) and the PCC, or any other location acceptable to the area EPS operator on the local or area EPS following a target volt-var characteristic curve.



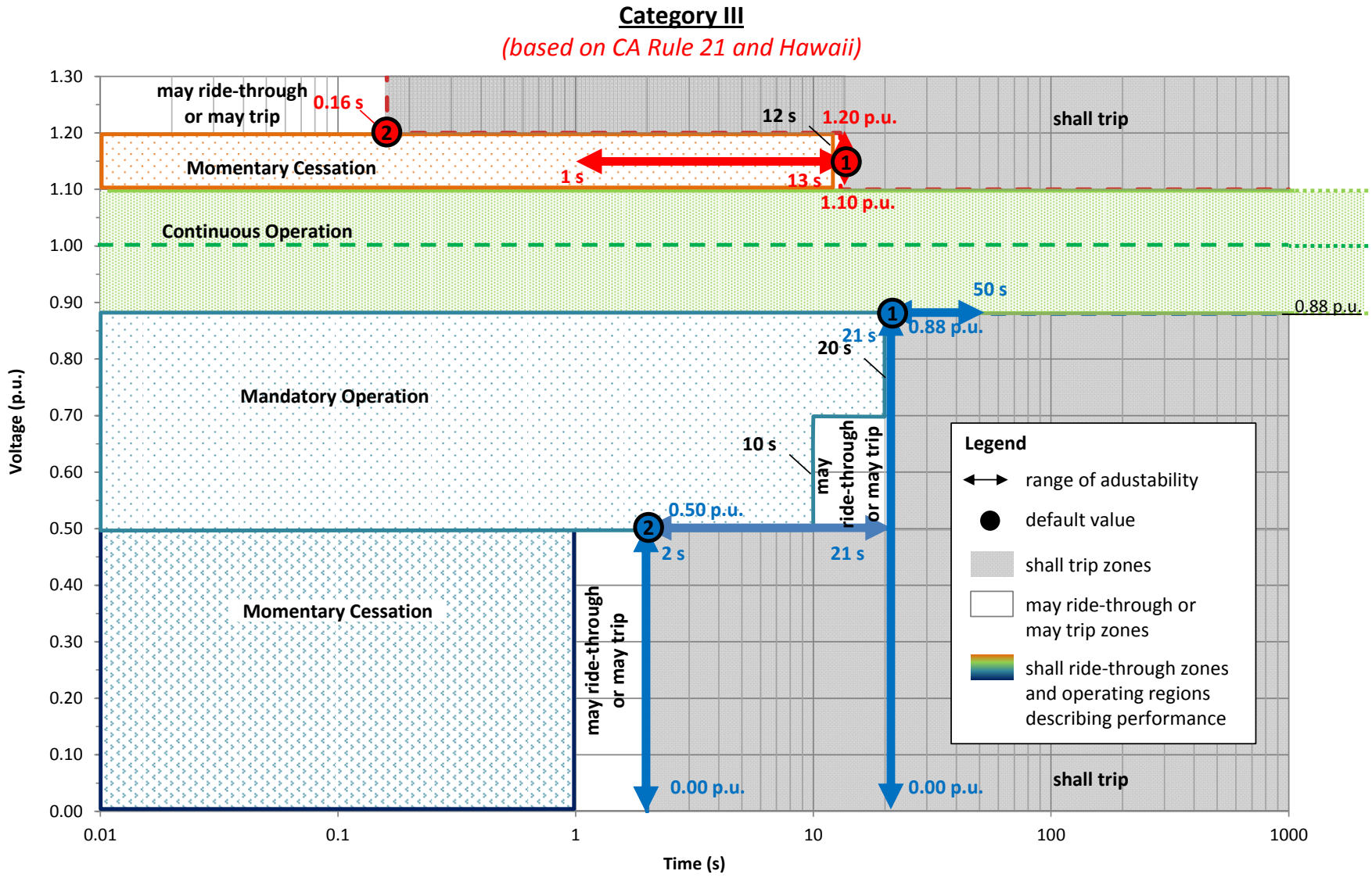

| Volt-var Parameters | Definitions | Default Values for Cat I DER | Default Values for Cat II & III | Optional Adjustable Range | |
|---|---|---|---|---|---|
| | | | | Minimum | Maximum |
| $V_{Ref\ fixed}$ | Reference voltage | 1 pu | Nominal Voltage ($V_N$) | 0.95p.u. | 1.05p.u. |
| $V_2$ | Dead band lower Voltage Limit | 1 pu | $V_{Ref}$ – 0.02p.u. | Cat I: $V_{ref}$<br>Cat II & III: $V_{Ref}$ – 0.03p.u. | $V_{Ref}$ |
| $V_3$ | Dead band upper Voltage Limit | 1 pu | $V_{Ref}$ + 0.02p.u. | $V_{Ref}$ | Cat I: $V_{ref}$<br>Cat II & III: $V_{Ref}$ + 0.03p.u. |
| $V_1$ | Voltage at which DER shall inject $Q_1$ reactive power | | | $V_{Ref}$ – 0.1p.u. | $V_{Ref}$ |
| $Q_1$ | Reactive power injection at voltage V1<br>Note: The DER reactive power capability may be reduced at lower voltage. | | lity | 0 | Cat I: 100% of stated capability[1]<br>Cat II & III: 100% of stated capability[1] |
| $V_4$ | Voltage at which DER shall absorb $Q_2$ reactive power | 1.1 pu | $V_{Ref}$ + 0.08p.u. | $V_{Ref}$ | $V_{Ref}$ + 0.1p.u. |
| $Q_4$ | Reactive power absorption at voltage V4 | 50% of stated | 100% of stated reactive capability | | 100% of stated |


- The target characteristic curve shall be configured in accordance with the default parameter values specified in Table TBD for the given DER category.

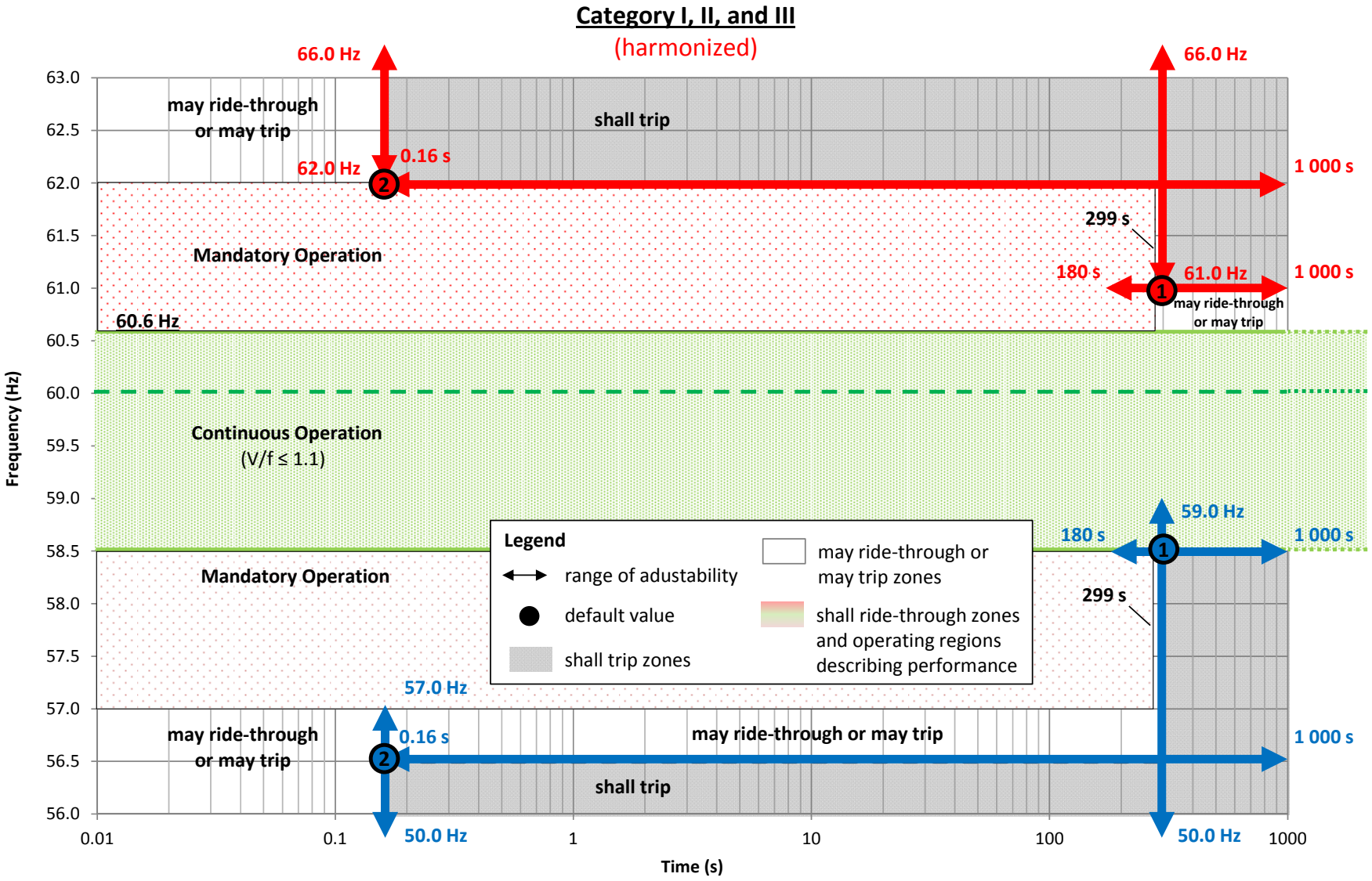
# IEEE P1547: Foundations for Ride-Through Requirements

| Requirement | Category | Foundation | Justification |
|---|---|---|---|
| **Voltage Ride-Through** | Category I | German grid code for medium voltage-connected synchronous generator-based DER | • *Essential* bulk system needs<br>• Attainable by all state-of-the-art DER technologies |
| | Category II | NERC PRC-024-2 but w/o stability exception, extended LVRT duration for 65-88% $V_{nom}$ | • *All* bulk system needs<br>• Coordinated with existing reliability standards<br>• Considering fault-induced delayed voltage recovery |
| | Category III | CA Rule 21 and Hawaii, minor modifications | • All bulk system needs<br>• Considering fault-induced delayed voltage recovery<br>• Distribution system operation |
| **Frequency Ride-Through** | All Categories (harmonized) | CA Rule 21 and Hawaii, exceeds PRC-024-2 | • All bulk system needs<br>• Low inertia grids |

# Proposed Voltage Ride-Through Requirements for Category III



# Proposed Frequency Ride-Through Requirements for All Categories








EPRI ELECTRIC POWER RESEARCH INSTITUTE

# IEEE P1547 WG Meetings

1. April 23-25, 2014 Las Vegas, NV
2. June 26-27, 2014 Las Vegas, NV
3. Nov 4-7, 2014 Atlanta, GA (NERC)
4. Feb 10-12, 2015 Arlington, VA (NRECA)
5. June 1-3, 2015 Waltham, MA (National Grid)
6. Oct 27-29, 2015 Tempe, AZ (Salt River Project)

- …
- Fall 2016 WG final draft to IEEE for Ballot (Target)

http://grouper.ieee.org/groups/scc21/1547_revision/1547revision_index.html

# Questions

**Contacts:**

- Aminul Huque – 865.218.8051, mhuque@epri.com

# Together…Shaping the Future of Electricity